Influence of Wave-Front and Atrial Tissue Properties on Eikonal Model Simulations

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Background

Atrial fibrillation (AF) is the most common arrhythmia in humans and current treatments are sub-optimal. Computational models have provided meaningful contributions in this field during the last years. However, the application of biophysically detailed models in the hospital is very challenging because their simulations are incompatible with regular procedure times. Eikonal models are significantly faster but less detailed. For example, they neglect the influence of wave-front (WF) and geomtrical tissue properties on conduction velocity (CV). Improvement of Eikonal models could contribute to better estimate AF risk.

Objective

To incorporate the influence of the geometrical properties of the electrical WF and atrial tissue on CV in Eikonal simulations.

Methods

The geometrical properties of the atrial tissue were set as suggested by Rossi et al. [1]. We conducted bidomain simulations in openCARP to calculate CV in meshes with different wall curvature and thickness. [2] The results were used to create a regression model which predicts CV when wall curvature and thickness are provided as inputs. Then, the predicted CVs were used as input for Eikonal simulations solved by the fast iterative method (FIM). Eikonal simulations and regression were performed in MATLAB.

Additionally, to incorporate the effects of WF properties, CV was obtained from bidomain experiments with different WF curvatures (WFC). A linear regression model was created to calculate CV based on WFC. The FIM was modified to calculate the propagation of the WFC and its influence on the CV.

Results

When including the geometrical properties of the atrial tissue, comparison between Eikonal simulations before and after the CV pre-processing shows a qualitative improvement, considering Rossi et al. as the reference. [1] In the experiments varying the WFC, there was a decrease of 55% of the mean error with respect to the bidomain simulations in the case with the highest curvature.

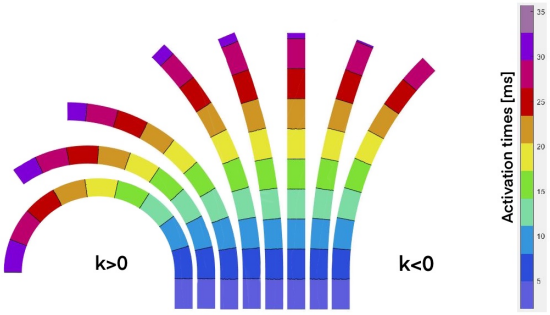

Figure 1: Eikonal simulations with different tissue curvatures.

Discussion

Changes in the Eikonal model provided more similar results to the bidomain simulations. This progress could lead to a better and faster risk assessment of patients with AF. However, further work is required to account for the combination of the studied effects in whole atria simulations.

References

[1] S. Rossi *et al.*, "Muscle thickness and curvature influence atrial conduction velocities," *Front Physiol*, vol. 9, p. 1344, 2018.

[2] G. Plank *et al.*, "The opencarp simulation environment for cardiac electrophysiology," *Comp Meth Progr Biomed*, p. 106223, 2021.

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